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ACCOUNT

OF

SIR CHARLES BELL'S CLASSIFICATION

OF THE

NERVOUS SYSTEM.

BY

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NOTE.

This Essay was composed as an Appendix to the third Edition of Sir Charles Bell's work, "The Anatomy and Philosophy of Expression," published posthumously.

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ON THE

NERVOUS SYSTEM.

In many parts of this volume references are made to an Essay upon the Nervous System; and such an essay was contained in the last edition: but it was found that the author had drawn his pen through that essay, and had left nothing new to supply its place. It cannot be doubted that he intended to recompose that part of his work; and as some account of his observations on the nervous system bearing upon the questions here discussed may be interesting, I have been requested to give a short review of his opinions. I enter upon the task with feelings of great diffidence.

It is stated, in various parts of the essays, that a distinct class of nerves is provided in the human body for controlling the organ of respiration; and that it is this class which is principally affected by passion and emotion, so as to give rise to the phenomena of Expression.

The organ of breathing is so constructed in man, that besides ministering to the oxygenation of the blood, its primary office in the economy, it is the instrument of voice and of expression,—two properties which bear relation to his intellectual nature. The apparatus required for adapting the organ of breathing to those superadded endowments, is altogether different from that which is found in the lower animals, where the organ is subservient

only to the purification of the blood: and as a correspondence must exist between the structure of the different moving parts of the frame, and the nervous system, which regulates the actions of the body, the change in the construction of the organ is accompanied with a change in the arrangement of the nerves. Accordingly the author of this volume found, by comparing the nervous system as it exists in inferior animals, with its order and distribution in man, that a distinct class of nerves is appropriated in the human frame to the organ of respiration: and to that class he gave the name *respiratory nerves.*

But this conclusion was not arrived at till many other important observations had been previously made by the author on the functions of the nervous system. Medical science has been indebted to him for improvements in this branch of physiology, only to be compared, for their extent and value, with those introduced by Harvey by his discovery of the circulation of the blood. Although no parts of the living body have excited greater interest, since anatomy was first studied, than the brain and the nerves, yet when Sir Charles Bell entered upon his researches into this subject, he found it involved in so much confusion, and surrounded by so many difficulties apparently insurmountable, that physiologists had almost ceased to prosecute it. Errors on points which bore on the first elements of the inquiry had taken deep root. He succeeded in removing these errors, and in establishing an entirely new principle of investigation; by adopting which, as his guide, he was rewarded not only by making discoveries of the utmost value to medicine himself, but by communicating a fresh impulse to the labours of other physiologists in the same field.

The error which formerly prevailed, and had the greatest effect in retarding improvement, was this: — It was taken for granted that all parts of the nervous system had certain general properties belonging to them in common; so that all were considered alike in function. The brain, including the spinal marrow, was looked upon as a common store, from which certain powers, such as that of motion, were issued to the body,

and into which others, such as sensation, were received, the nerves being regarded as the conductors; and, in conformity with that view, it was further supposed that any part of the brain, or any single nerve, had an equal power with all the rest, of bestowing the numerous properties commonly assigned to the nervous system. For the sake of illustration, let me take the nerves of the lower extremities. These come off from the spinal marrow. Now it was conceived that they were all simple in structure; and that each had the power of conferring motion on the limbs, and at the same time of giving sensation; and that the spinal marrow from which they arise, being a prolongation of the brain, had these two functions combined promiscuously in all its parts.

It is not difficult to explain how these mistaken views originated. In the first place, when we look to a nerve, there is nothing visible in the structure of the fibrils of which it consists to lead us to suppose that one set possesses different functions from the others: they are all exactly alike in size, colour, and consistence, and are held together in the same manner, in one common investing membrane or sheath. In the second place, although the brain is subdivided into numerous masses of different forms and dimensions, so as to give the appearance at first sight of its consisting of many separate organs, yet an uniformity prevails in its general structure, and the distinct substances of which it is formed are so diffused and intermingled with each other, that it seems as if its functions must be common and possessed equally by all its parts. Again, the phenomena of certain diseases and accidents, occurring almost daily, must have strengthened these erroneous opinions. When the trunk of a nerve, in its course along one of the extremities, is cut across in a wound, the lower part of the limb thus isolated from the brain is deprived at once both of motion and sensation: if the spinal marrow be crushed or wasted by disease, total paralysis ensues; that is, the limbs lose motion and sensation conjointly. When a man is struck down by apoplexy from a sudden effusion of blood into the brain, numbness or insensibility accompanies the loss of

motion. These circumstances taken together were all likely to mislead, and may account for the error mentioned above having held its place so long.

After Sir Charles Bell began to investigate the subject, it soon occurred to him that great inconsistencies were involved in the opinions generally maintained. One of the difficulties which struck him most was the following: — When we suppose a nerve in the act of exciting a muscle to contract, it necessarily implies that the stimulus by which it produces that effect travels *outwardly*, — that it originates in the brain, and is conveyed externally along the fibrils of the nerve to the muscle. But when we suppose a nerve in the act of giving rise to a sensation, it implies that the impression which occasions the sense is first communicated to the extremity of the nerve expanded upon the skin, and is then conveyed *inwardly* till it arrives at the sensorium. Hence the peculiar influence which causes muscular action travels in one direction; and that which causes sensation, in exactly the opposite direction: and it seemed impossible to the author that they could both be conducted by the same nerve.

The fundamental principle, which may be looked upon as the origin of all the author's important discoveries, was thus announced. "The nerves of the body possess distinct and appropriate functions, corresponding with the parts of the brain and spinal marrow with which they are connected at their roots; and when a nerve, which appears simple, is found to bestow more than one endowment, it is a sign that that nerve has more than one origin from the brain, and consists in reality of several nerves joined together."

The mode in which this principle was demonstrated and established as a law in physiology, was the following: —

The author first directed his attention to the nerves of the organs of the senses. These nerves were formerly conceived to be allied so closely to each other, that the functions belonging to them were regarded rather as modifications of one common property, than distinct and specific; hence it was supposed that the nerve of one organ could be the substitute for the nerve of

another organ, if transposed to that organ: for example, it was believed that the optic nerve, on which vision depends, could bestow sensation or pain, like a nerve of the skin. But the author proved this to be incorrect, and that each nerve is limited to receiving a distinct impression, appropriated to it exclusively. Thus the nerve of vision can only give ideas of light and colour;* the nerve of hearing, impressions of sound; the nerve of smelling, the perception of odours; and so on. He further shewed that these special properties depended on each of the nerves arising from a distinct portion of the brain provided for receiving its own peculiar impression. This fact could not be easily demonstrated by referring to the human brain alone, where the structure is complicated to the greatest degree, owing to the organs of sense and the intellectual capacities related to them, having reached their highest point of developement; but it could be satisfactorily made out with the assistance of comparative anatomy. When we examine the lowest classes of animals, it is not found that they have the same number of organs of sense which belong to the higher. On the contrary, the organs are bestowed gradually, one after another, in correspondence with the progressive advancement of the creatures in the scale of animal existence; and it is further observed, that the part of their nervous system, recognised as similar to the brain, becomes more complex in proportion as the organs multiply. Each nerve can be traced at first into a little ganglion or accumulation of nervous substance, which is concluded to be the source of its particular power: they increase in number as the organs increase; and

* He illustrated this fact in the following manner: — Pressure applied to the surface of the eye, between the eyelids, gives rise to pain, more acute than that felt in the skin generally, but still of a similar kind; while the same degree of pressure applied to the ball of the eye, so as to affect the retina within, produces the appearance of a halo of differently coloured light before the eye, or a totally different kind of sensation from the former. In couching for cataract, the needle, when piercing the outer part of the eye, gives rise to pain,— to a sensation like that of pricking the skin; when it transfixes the retina, an appearance, as if a spark of fire had entered the eye, is produced.

they become larger and more complicated in organisation in proportion as the organs are more perfectly developed, and the animal more elevated in its position. These ganglions are called after the organs of sense over which they are supposed to preside; and hence they get the names of optic ganglions or lobes, olfactory lobes, auditory lobes, &c. This was the first step taken by the author to shew that the nerves possess distinct functions, and that they obtain these from being connected with subdivisions of the brain, which have also distinct endowments.

The next stage in his progress was marked by more striking results. His object was now to explain the cause of the nerves, which are distributed to the body generally, having the double property of giving motor power to the muscles and sensation to the skin.

The way in which he proceeded was this. He took the different nerves known to possess these two functions, and traced them to their roots in the brain. It has been already noticed, that when we examine a nerve situated in a limb, it is found to consist of numerous fibrils, all similar in structure, and held together by a common membraneous sheath; no indication appearing of one set having different functions from the others. But if we follow the nerve in its course towards the spinal marrow or brain, we shall find that, as it approaches either of these organs, and before it terminates, *it subdivides into two distinct roots* — one of which can be traced into a division of nervous substance distinct from the other, and one of which is further distinguished by having a swelling upon it, called a ganglion, which the other has not.

Now Sir Charles Bell was led by this observation of the anatomy to suppose that each of these roots had a distinct function; that one bestowed the power of motion and the other sensation; and that the reason why the whole nerve possessed both of these properties was, that it consisted of two distinct nerves joined together. He proceeded, therefore, to verify this opinion by experiment; and he confirmed it by the most satisfactory evidence. He shewed that the root which passes to the

posterior part of the spinal marrow, and has a ganglion upon it, gives sensation alone, while that which arises from the anterior part gives motion alone. He thus established for the first time the important fact, that the nerves of Sensation are distinct from those of Motion.

It may here be observed, that by far the greatest number of the nerves which provide the body with motion and sensation arise from the spinal marrow; only a few come directly from the brain. Sir Charles Bell was led, in the next stage of his progress, to compare these nerves with each other; and by doing so, he obtained several interesting confirmations of the truth of his views.

He was particularly struck, in the first place, by noticing that the divisions of the spinal marrow, with which the roots of motion and sensation are respectively connected, are prolonged, as distinct tracts of nervous substance, into the brain; and that they continue to give off nerves, in regular succession, after they have reached that organ. Again he observed an important difference between the mode in which the nerves of the brain go to their destinations, and that in which the spinal nerves proceed. With the exception of one nerve, the *fifth* (to which I shall presently refer as being similar both in origin and functions to the nerves of the spine), all the cerebral nerves escape from the skull by distinct holes, so as to be simple in structure, instead of consisting of two roots joined together. Accordingly, greater facility was afforded for investigating the functions of these nerves, than was the case with the spinal nerves.

The first nerve of the brain selected for experiment was that which passes to the tongue, and is called the *ninth*. It is to be remarked that this nerve arises in all respects like the anterior root of a spinal nerve, which, it has been seen, is the one that confers motion; that is, the ninth has its origin from the division of the spinal marrow, which gives off the anterior roots, just as that division begins to expand and mix with the brain: it then passes immediately, without being joined by the fibrils of any other nerve, through an appropriate hole in the base of the skull, to the tongue, in the muscular substance of which it is lost.

When this nerve was cut across in experiment, it was found that the tongue was deprived of the power of motion; but its sensibility remained unimpaired; thereby proving conclusively that, like the anterior roots of the spinal nerves, the ninth confers Motion alone.

The author next selected for experiment another nerve, which springs from a different part of the brain from the ninth,—the facial nerve, or *portio dura*. This nerve arises by a simple root, and, without mixing its fibrils with those of any other, appears externally before the ear, as represented by A in Plate IV., and is distributed to the face. It had been hitherto believed that the portio dura was capable of bestowing both motion and sensation. But the author proved that this nerve was limited to giving Motor power. By making a small incision through the skin, not larger than that for bleeding, he exposed the nerve in a monkey,—an animal which he considered better adapted than any other for the experiment, owing to the well-known mobility and activity of its features: when the nerve was laid bare and cut, the motions of the corresponding side of the countenance were at once and entirely extinguished; but the sensibility was unimpaired. It was even observed, as an additional proof that sensation does not depend upon the portio dura, that the animal manifested no signs of pain during the act of cutting it through.

Having obtained these conclusive proofs, with others which I need not detail, that each nerve of the brain which arises by a single root has a distinct and appropriate function, instead of possessing various combined functions, as was formerly supposed, it was next important to examine the *fifth* nerve, which, it has been stated, is distinguished from the others by resembling the spinal nerves. It may be briefly mentioned that this nerve arises from the brain by two roots, having a similar structure in every respect to those of the nerves of the spine, except that in the fifth, one root is much larger compared with the other, than in the spinal nerves; the root which has a ganglion upon it being about five times greater than that which has no ganglion. It may also be stated that, shortly after its origin, the whole nerve

subdivides into three great trunks, which ramify over the entire head; and that the smaller root accompanies only one of the trunks, called the third or inferior maxillary, which supplies the lower part of the face and the muscles of the jaws. Hence the first and second great branches are simple in structure, being formed entirely of fibrils from the larger, or ganglionic, root; while the third is in part compound, from containing fibrils of the lesser root.

Referring to Plate IV., it may be observed that two large branches, one above and the other below the orbit, marked respectively I. and II., issue from the bones of the face to go to parts already abundantly supplied by the portio dura: these are branches of the first two trunks, derived from the ganglionic root alone. Now it was found that when these branches, called the supra-orbitary and infra-orbitary nerves, were exposed in a living animal, it gave the most acute pain to prick or squeeze them; and when they were cut across, the whole surface of the face to which they are sent, was deprived instantaneously of sensation; so entirely was the sensation destroyed in these parts by this experiment, that the skin could be cut or pinched without the animal being conscious of the injury; and yet the motion of the parts was perfectly retained, because the portio dura was untouched. Again, when the third or inferior maxillary trunk, composed of the two roots conjoined, was similarly exposed and cut across, pain was experienced in the operation, and the parts to which it is sent were deprived of sensation, but an additional effect was produced — the muscles of the jaws, to which the smaller root goes, were paralysed. Hence the conclusion was obvious, that the larger root of the fifth nerve is endowed with Sensation and the smaller with Motion; and it is only where the two are combined that the nerve can give both properties at once.

It will be acknowledged that the facts now stated were sufficient to prove the truth of the general proposition, that nerves of Sensation are distinct from nerves of Motion; and that the distinction depends on the portions of the brain with which they are connected at their roots, having corresponding appropriate

endowments. Soon after the first experiments were performed, additional confirmation of his views was obtained by Sir Charles Bell, in studying the phenomena of disease: numerous cases came under his observation* where morbid action in the brain or spinal marrow, or at the roots of the nerves, gave rise to effects in the human body, exactly similar to those produced by the experiments on the lower animals.

For example, tumours sometimes grow within the canal of the vertebral column, where the spinal marrow is lodged, and develope themselves in such a manner as to destroy one set of the roots of the nerves without involving the other: in these cases, only one function of the spinal nerves is lost. If the anterior roots be affected, there is loss of motion; and if it be the posterior roots, there is loss of sensation; and the patient is in the singular condition of having feeling in the limb, although he cannot move it, or he may be able to move it, and have no feeling.

Cases of a similar kind were met with more frequently in the head; owing to the nerves of the brain being more apart from each other at their origins than the roots of the spinal nerves. Thus many cases were observed where the two nerves which supply the face, the one with motion, and the other with sensation, were affected separately by morbid action, so as to be deprived of their functions. While the branches of the fifth nerve go straight outwards to reach the face by the shortest route, the portio dura takes a circuitous course to arrive at the same part: it passes through the bone which contains the ear and behind the lower jaw, and is, consequently, liable to be involved in disorders, from which the branches of the fifth are free. When the portio dura was thus affected by itself, the patient could no longer knit his brows, close his eyelids, inflate his nostril, or hold any thing between his lips; expression was entirely lost in the side of the face, and there was actual distortion, owing to the muscles of the sound side dragging the paralysed cheek and lips towards them; but there was no diminution of sensibility in the

* They were recorded chiefly by his zealous assistant in these pursuits, Mr. John Shaw.

half of the face, which was so completely deprived of motion.* Again, when the fifth nerve,— or, more properly, those branches of it which arise from the larger root alone,—were implicated in disease, so as to have their structure destroyed, sensation was lost, while motion was unimpaired. Taking even the most delicate and acutely sensible part of the face, the membrane which lines the eye, it might be scarified without the patient winking, or, in fact, being conscious of the operation.† In painful affections of the face, as tic-douloureux, the fifth nerve was found to be the source of the suffering. When disease affected a part where the smaller or motor root was included with the larger, besides the pain and loss of sensation, the muscles which move the lower jaw were paralysed, these being controlled by that root.

From such examples some idea may be formed of the advantages conferred upon medicine by the discoveries which have been described, and especially of the new light they threw upon diseases of the brain and spinal marrow. While the belief prevailed, that every nerve, from whatever part it came, had the same kind of functions, and that the different divisions of the brain and spinal marrow were also alike, it followed that, when a case was met with of partial loss of sensation or of motion in any part of the body, the physician was led to conclude that disease had commenced in the brain; and his treatment was conducted on

* And it might be added, that no pain, arising directly from the disease in the nerve, attended the loss of function. Patients are seldom aware of their face having become paralysed, until told by a friend, or it has been observed by themselves in the mirror. This is accounted for by the portio dura being simply a nerve of motion, and having no power of bestowing sensation or giving pain.

† The loss of sensation in the eye, from lesion of the ophthalmic branches of the fifth, is often followed by inflammation, which terminates in the destruction of the organ. This is caused by the eye having been deprived of its most important guardian,—namely, the sensibility which induces not only winking, but other efforts to protect the tender surface from irritation. Cases are sometimes met with where the surface of the eye has lost its sensation; but where the upper eyelid has become permanently dropped (owing to another nerve, the third, being also affected), so as to cover it, and defend it from injury: in these cases, inflammation does not occur, and the eye preserves its transparency.

that supposition. But when it was learned that the nerves had distinct endowments, it was only required, in such cases, to be acquainted with the particular uses and the anatomical course of the individual nerves distributed to the affected part, to be able to determine at once, whether the disorder was in one of the nerves, after it had been given off from the brain, and therefore a comparatively harmless complaint, or if it were situated in that important organ itself, and of a serious nature. In short, the knowledge now acquired of the nervous system lends, every day, the most valuable aid to the practitioner; it gives him means, not formerly in his power, of exploring disease, and of tracing it along the nerves to the precise spot where it is situated.

But when Sir Charles Bell reached this stage of his progress, and had thus settled the distinction between the nerves of sensation and of motion throughout the body, he became aware that other important questions remained to be examined before we could have a satisfactory knowledge of the functions of all the nerves. The subject which principally attracted his attention was a contrast between the distribution of the large class of nerves which arises from the whole length of the spinal marrow, together with certain nerves of the brain, and a comparatively small class, which arises from the Medullá Oblongata, a division of the nervous system placed at the point where the spinal marrow and brain join each other.

When he looked to the nerves of the spine, he perceived their chief character to be, that they supply the body generally: they go to the neck, and even to a part of the head; they go to the arms; they supply the trunk; and they are sent to the lower extremities. To all these parts, he had also ascertained that they give motion by one of their roots, and sensation by the other. He had demonstrated, at the same time, that the fifth nerve of the brain is exactly of the same nature as the spinal nerves: it is composed of two roots, by one of which motor power is given to the muscles of the jaws, and by the other sensation to all the surfaces of the head. Now, placing the spinal nerves and fifth pair together as one class, and associating the nerves of the organs of the senses with them, he considered that there was here a system

of nerves competent, at first appearance, to fulfil all the essential services of a nervous system.

He turned his attention, in the next place, to the nerves which come off at the medulla oblongata; being four in number, and varying in size and extent of distribution. The chief circumstance which gave interest to these nerves was, that they arise from a small circumscribed part of the nervous system, distinct from those divisions which give origin to the nerves of the former class; and they pass to a limited extent of the body, already plentifully supplied by that class.

From this observation Sir Charles Bell inferred that the nerves of the medulla oblongata could not thus arise from a distinct portion of the brain, and course to parts of the frame already sufficiently supplied by nerves from a different quarter, for the mere purpose of giving the same powers, or even an addition of the same powers, conferred by the other nerves. He thought, on the contrary, that they must be sent to bestow properties which the spinal nerves and fifth are incapable of giving. He saw, at least, that our knowledge of the uses of the first-mentioned class could not be considered perfect, until the question was properly solved, Why is the other class superadded? He accordingly endeavoured to remove that difficulty.

He began this part of the inquiry by seeking to discover whether any common character could be proved to belong to the nerves arising from the medulla oblongata; and, with that object, he studied carefully the functions of the organ to which they are severally sent. He observed that they all agree in one thing, namely, that they are distributed to parts of the frame which together form the organ of Respiration. The portio dura is sent to the nostrils and mouth, the exterior orifices of the tube which leads to the lungs; the glosso-pharyngeal goes to the posterior openings of the nostrils, and upper part of the windpipe and fauces; the superior and inferior laryngeal nerves, branches of the par vagum, supply the larynx, which is the organ of voice; the par vagum then descends into the chest, and is distributed to the windpipe, lungs, and heart; but branches, also,

go along the gullet to the orifice of the stomach, which is surrounded and guarded by muscular fibres of the diaphragm; the spinal accessory nerve is sent to muscles of the shoulders and neck, which combine with those of the chest in dilating the lungs. Being satisfied, therefore, that the nerves of this class belong to the organ of breathing, he proceeded next to ask, Why this part should have a distinct set of nerves provided for it? Why the spinal nerves and fifth nerve should not have been sufficient to control the various movements of breathing?

But that question, he soon perceived, could not be answered by confining his attention to the organ of respiration merely as it is found in man. It was necessary to follow the developement of the apparatus in the animal kingdom generally, and to study the uses to which it is applied in the lower, as well as the higher, animals. By such a course of investigation alone, did he think that this problem could be solved.

It deserves to be particularly remarked that the mechanism of the organ of respiration, as it exists in the lower animals, is very different from what it is in the higher. And the reason is obvious. In the lower classes of animals the organ is limited to one function—that, which is its primary office in the economy, of oxygenating and purifying the blood; while, in the higher classes, it becomes also the organ of Voice; and, in man, where it is in the perfection of organisation, it is the instrument of Articulate Language, as well as of Expression.

Here, then, may be perceived the groundwork of the explanation given by Sir Charles Bell why, in man and the higher classes of animals, the organ of respiration is provided with a series of nerves distinct from those which confer motion and sensation on the body generally. He considered that, in the course of its developement, from the simplest to the most complex animals, this part undergoes such great and remarkable changes in its construction to become the organ of Voice in addition to that of mere respiration, that a new class of nerves was required to regulate the actions of the superadded mechanism.

Let us reflect on what is necessary in the structure of the organ of respiration to form it as the instrument of voice. The

first essential thing is, that the air for oxygenating the blood shall be received into a closed cavity, communicating with the external atmosphere by a single tube; the second is, that this cavity shall be capable of contracting on the volume of air within, so as to expel it along the tube, with a stream strong enough to vibrate and produce sound. This is the simplest view of a chest, containing lungs, and of a trachea opening at the nostrils and mouth.

But it were a mistake to suppose that the form of respiratory organ here described is one met with generally in the animal kingdom. So far from this being the case, it is not till we ascend to the class Vertebrata, that we find the earliest and faintest indications of a true chest and windpipe.

In the lowest classes of animals, those a single grade in the scale above vegetables, there is neither circulating system nor distinct respiratory organ. But as soon as a circulating system appears, traces are also perceived of an apparatus for oxygenating the blood. The organ, however, is of the most simple structure, being merely a few prolongations of the integument of the animal, disposed in the shape of tufts or fringes, which float freely in the water, and expose the blood to the oxygen contained in that element. As the circulating system becomes more distinct, the fringes are exchanged for small sacs within the animal, formed by the integument folded inwards upon itself. The apparatus for respiration in insects, is a modification of the latter kind of structure: ranged along the sides of their bodies, at regular intervals, there is a succession of holes, which are the openings of a series of infinitely small tubes, that extend in all directions through their interior; these openings and tubes conduct the air into their bodies, where the oxygen purifies the blood. A higher form of respiratory organ is presented in branchiæ or gills. These are possessed by such animals only as have the circulating system so far developed, that the elements of a heart, and a distinct set of vessels for conveying the blood to be oxygenated, appear for the first time; and they therefore indicate a greater concentration both of the respiratory organ and of the circulating system. But even gills pass through many gradations

before they acquire that high degree of developement with which we are most familiar in fishes.

What we have chiefly to remark in all these modes of respiration is, first, that until we arrive at the order Fishes, the lowest of the vertebrata, the mouth has no connexion with the organ of breathing;—it is limited, in all the Invertebrata, to the purposes of *nutrition:* and, secondly, that not only is the earliest example of the mouth being an orifice common for the food and breathing, seen in fishes, but they have an internal skeleton in which is blocked out, as it were, the first rude form of a chest for containing lungs, and for inhaling the breath through a single tube, the trachea.

It may be new to many of the readers of this work to be told that the air-bladder, which serves in most kinds of fishes to accommodate their specific gravity to the degrees of density of the water in which they swim, is, in reality, an elementary lung. Yet this is proved to be the case by many facts in comparative anatomy. It is sufficient to state, that a set of fishes exist called sauroid (from their resemblance to the inferior kinds of reptiles), in which the air-bladder communicates with the mouth by a tube (termed ductus pneumaticus), which resembles, in all respects, a windpipe; and these fishes, when left on dry land, can respire by this apparatus independently of their gills. The same structure passes through various gradations in other animals intermediate between fishes and reptiles, till the gills at length disappear, and the air-bladder becomes a more perfectly organised lung.

If we continue to trace the mechanism by which the sac, thus introduced for the first time in connexion with the mouth for the purposes of respiration, is alternately expanded and compressed by an apparatus of ribs and muscles, to receive and expel the air, it will be found that it makes considerable advance in its developement in the order reptilia. In the lowest of this order, as the frogs and tortoises, the form of the chest is so imperfectly matured that, instead of the sac or sacculated bag, which constitutes their lungs, being filled by an expansive motion of that cavity, it is distended by successive actions

of the mouth, like swallowing; and nostrils are now first perceived in communication with the throat. In the higher orders, as the crocodile, distinct ribs, and muscles for moving them, are provided; and the process of respiration, although carried on sluggishly, in accordance with their being cold-blooded animals, nearly resembles that with which we are best acquainted in mammalia and in man.

But there is an important distinction between the structure of the chest, as seen in reptiles or in birds (which are next above them in the chain of animal existence), and that in mammalia. In reptiles and in birds, no partition exists between the abdominal and thoracic cavities, so that the ribs form a common covering for the viscera of nutrition, and the lungs, which lie in contact with them. It is not till we ascend to mammalia that a *diaphragm* is introduced, a septum composed of muscular fibres, which stretches across from the lower border of the ribs on one side to that of the other, and forms a complete boundary between the abdomen and chest. Now the diaphragm has not only the effect of circumscribing the space for containing the lungs, and thereby giving greater force to the expansion and contraction of these organs, but it acts itself as a powerful muscle of respiration in dilating the area of the chest. In short, when a diaphragm is added, the organ of breathing attains its highest state of concentration in the animal kingdom; and it is not only adapted in the most admirable manner for oxygenating the blood, but the mechanism surrounding the lungs is so adjusted, that the air can be expelled through the larynx, the organ of voice, and through the mouth, the organ of speech, with so strong an impulse as to produce Vocal sounds and Articulate Language.

When the chest acquires the compact form and the new properties just described, there follow several modifications in the structure of different parts of the frame, which do not, at first, appear to have any direct relation to the organ of breathing. Peculiar sensibilities are also introduced, with various combined actions of muscles far apart from each other, obviously designed to guard the organ from injury, and to perfect it as the instrument of Speech.

The first example, I shall take from the circulating system. It is found by comparative anatomy that, according as the apparatus of respiration becomes more perfectly organised, the heart and blood-vessels begin to be subdivided into two distinct systems, the one for purifying the blood, and the other for distributing it over the body. This is the origin of that distinction which comparative anatomists draw between the *pulmonic* circle, including the part of the heart and blood-vessels belonging to the lungs, and the *systemic* circle, which sends the blood over the body, and returns it to the heart. This separation takes place in a slow and gradual manner in the animal kingdom, and it is only seen to be complete in the warm-blooded animals. Thus, in man, the division of the circulating system appropriated to the lungs or the oxygenation of the blood, consists of cavities of the heart and of blood-vessels, which are quite distinct from those provided for propelling the blood over the body. Yet these two divisions act in perfect concert with each other, a concert mechanically secured by the peculiar structure of the heart; for the two sets of cavities are joined together to form a single organ, and they contract in unison. Thus, so close a sympathy is established between the heart and the organ of respiration, that any interruption to the entrance of air into the chest will not only affect the action of that division of the heart which belongs to the lungs, but it will disturb that part, joined to it in structure, by which the purified blood is conveyed through the body. Hence, the agitation and palpitation of the heart, so much dwelt upon in this volume, caused by disturbances in the action of respiration, whether from bodily exertion or mental emotion.

Another point, still connected with the circulating system, deserves to be noticed, as throwing light on some of the questions treated in the work. The blood which returns to the heart by the veins, flows towards the chest in a slow and easily interrupted stream; the force which propelled it when issuing from the heart by the arteries, being exhausted before it enters the veins. From this weakness of the current, it follows that the blood collected in the great veins close to the entrance of the chest—as the jugular veins, for example—may be stopped by a slight cause; when

congestion of the minute branches will be the consequence, and serious injury may be occasioned to the more delicate organs from which the blood returns. Now there are certain conditions of the chest in breathing, during which the blood is thus interrupted. As we draw in the breath, the blood flows along the veins with perfect facility, because the superior opening of the chest is then enlarged, and the suction, which draws the air into the windpipe, has also the effect of increasing the force of the current of blood. But when we expel the air, and thereby diminish the area of the chest, an obstruction takes place in the flow of blood in the veins, and if the act of expiration be strong, regurgitation may be produced. This interruption, and retrograde motion of the blood in the large veins of the neck, gorges the smaller vessels; the effect of which may be seen in a person seized with a fit of coughing or of sneezing: for his face then becomes suffused and red, and the superficial veins turgid with blood. It is therefore obvious, that if the veins of the surface of the head become congested, in such violent conditions of breathing, the deeper veins, returning the blood from the brain and the eye, will also be over distended from the same cause. Consequently, these important organs will be in danger of suffering serious injury to their textures from the loaded and turgid condition of the veins. But both organs are defended from such dangers by a beautiful arrangement of the muscles of the neck, which cover and protect the large veins. These muscles combine in sympathy with the movements of the chest, so as to compress the veins when there is a tendency to regurgitation, and to take pressure off them when the chest is expanded. It is further to be noticed, that the flat web of muscular fibres which covers the eye—the orbicularis muscle—is a part of the same provision. It acts in compressing the eye-ball whenever the chest is violently contracted; by this means it closes the veins at the back of the orbit, and prevents engorgement of the fine branches which ramify on the delicate coats within.*

* The orbicularis muscle is wanting in animals which have not the same concentrated apparatus for breathing as man. I have shewn elsewhere that in man and mammalia another provision exists besides that mentioned in the text,

I shall offer one other illustration of the new sympathies and arrangements in the actions of the muscles which are introduced into parts of the frame originally unconnected with the organ of breathing, to accommodate them for its becoming the instrument of voice in man.

We are so familiar with respiration through a mouth and nostrils, that we are led to look upon these parts as necessary to every apparatus for breathing. But it has been already stated that it is only in the class vertebrata, commencing with fishes, that the mouth has any relation to the function of breathing. In all animals lower in the scale, the openings in their bodies for the reception of air or water in respiration, are quite distinct from the oral aperture, as it is called, and placed at a distance from it. In short, the mouth is exclusively an inlet for the food in the invertebrata.

When so important an office is added to the mouth in the higher animals as that of receiving air in its passage to the lungs, it is obvious that many changes must accompany its newly acquired character. To adjust this opening for two functions so dissimilar as breathing and taking in food, and to ensure regularity in the performance of a process so vital as that of breathing, we find that a new mechanism, with appropriate muscles, and new sensibilities to animate these muscles, are introduced into the animal frame.

This is not the place to enter minutely into the subject; but I request the reader's attention to one or two examples of the mode in which the mouth and throat are protected in their

for guarding the eye against the irregularities of the venous circulation. The veins which ramify in the interior of the organ between the delicate membranes that support the retina, join the larger trunks, before these pass out from the eye-ball, in a peculiar manner; each minute branch makes a circular sweep so as to describe nearly a complete circle, previous to entering its principal vein. These small vessels are so numerous that they quite cover the surface, and being arranged in concentric circles, they produce an appearance from which the name *vasa vorticosa* has been applied to them. Nothing could be more admirable than this structure for breaking the force of a retrograde current of blood, and gradually diffusing it over the membranes. A similar appearance, though less distinct, may be observed in the superficial veins of the brain.

complex operations, by the sensibilities and reflex actions with which they are endowed.

Let us suppose that a morsel of food is chewed and ready to be swallowed. I only allude, in passing, to the peculiar arrangement by which it is provided that, while the mouth is obstructed by containing the food, the breathing proceeds uninterruptedly by the air passing along the nostrils, which open behind, and directly over the windpipe. When the morsel is propelled backwards, it comes in contact with a part of the cavity of the throat, which is endowed with a remarkable sensibility; it is of such a nature that, when excited, there is an irresistible desire to swallow; and the consequence is, that whenever the part is touched, a large class of muscles, consisting not only of those immediately adjoining it, but of others situated at a distance, are brought into combined action, to grasp and propel the morsel along the gullet. Here a great variety of movements take place consentaneously. The windpipe is closed by its valve, the epiglottis, falling over it; the posterior nostrils are shut by the folding upwards of the curtain, called the soft palate; certain strong muscles surrounding the upper part of the gullet compress the morsel, and urge it into that canal; but, before the food can reach the stomach, it must pass through muscular fibres of the diaphragm encircling the gullet; these fibres consequently relax, and there is a momentary interruption of the breathing. Now all these actions, which shew so remarkable a consent between the muscles of deglutition and of respiration, are excited and regulated by the peculiar sensibility seated at the back part of the throat. If, however, there should be any disturbance in the act of swallowing, and a small portion of the food should pass the wrong way, a different set of actions will occur, under the influence of another kind of sensibility. That is, if a crumb of bread should lodge in the throat, near the opening of the windpipe, a sensibility distinct from that which gives rise to swallowing will be excited, and will rouse the muscles into action, to produce a set of movements altogether different from the former. The same muscles will be combined in such a way

as to cause a succession of violent expirations, which will continue till the irritating particle is expelled from the top of the windpipe, and the danger of choking removed. It may be further noticed, that there are various other sensibilities seated in distinct parts of the passages, which differ in kind as well as degree from those just mentioned; and, when these are excited, similar concatenated actions of the muscles are produced, modified, however, according to the structure which requires to be cleared or defended.

The important circumstance that we have to attend to in all these examples of combined actions of the muscles, and fine sensibilities, provided in the face, neck, throat, and chest, is, that they have each a decided relation to the peculiar form of the organ of breathing in the highest animals; and that they are only required, when the mouth combines the two offices of being an inlet for the air and for the food.

It was from studying the human body with these views, that Sir Charles Bell was led to conclude that the nerves which arise from a part of the brain distinct from that which gives off the nerves generally, and which are distributed to the structures I have described, are bestowed in correspondence with the changes of mechanism, and the new relations established in the organ of breathing, during its course of developement in the animal kingdom. He concluded, that the main design of the progressive changes which the apparatus of breathing undergoes, from the lowest to the highest creatures, is to afford to Man an instrument corresponding with his superior endowments;—to supply him with an organ adapted to the great purpose of communicating thought, and evolving the powers of his Mind—the attribute by which he holds his exalted position in creation. He also thought that the same organization which serves for articulate language, or the production of those arbitrary sounds by which nations converse in speech, is appropriated to the universal language, understood by all, through which emotion and passion address us in the countenance, neck, and breast: hence, Sir Charles Bell believed that in man, the organ of

breathing is the organ of Expression; and that it is superintended in all its varied actions, by the class of nerves to which he gave the name Respiratory nerves.

The correctness of these opinions, so founded on a comprehensive survey of the organ of respiration in the animal kingdom, was more fully confirmed, when the author examined, in the next place, by a similar reference to comparative anatomy, the function of the class of nerves to which those of respiration were looked upon as superadded; namely, the Spinal Nerves and Fifth Nerve of the brain.

The extensive distribution of this system has been already noticed; it has been seen that it consists of double nerves, each composed of a root that bestows motion, and another that bestows sensation, and that they are sent to all parts of the body. But, although they are thus extensively distributed, Sir Charles Bell was much struck by observing, that they do not confer both of these properties equally upon the whole frame: he saw that sensation is bestowed indiscriminately or promiscuously, but that with regard to motion, the case is different: that there is a defined limit to the power which this class possesses of regulating the muscles. As this observation was of great importance in guiding him to the right view of the functions of these nerves, I may enter into a little more explanation concerning it.

If we direct attention to the spinal nerves, it will not appear that they are restricted in their distribution; they pass out directly from the spinal canal, to supply both motion and sensation equally, to the whole body, not excepting a part of the head. But, if we attend to the fifth nerve, it will be seen that, however freely it gives its sensitive branches to all the surfaces of the head, its motor branches are bestowed on the muscles of one organ alone: they are distributed (as I have already had occasion to notice) exclusively to the muscles of the jaws, and those muscles of the cheeks and lips which are associated with the jaws in mastication. Hence, viewing the functions of this great class, comprising the spinal nerves and fifth, we see that they give sensation to all parts of the frame, from the crown of the head to the toe; but they give motion only to the trunk, the

extremities, and the parts in the head by which *mastication* is performed.

It was from reflecting on this remarkable restriction of the fifth to the office of controlling the motions of the jaws, and inquiring into the peculiar relation which exists between the act of mastication and the functions bestowed by the spinal nerves generally, that the author was led to explain why these nerves should be associated to form a distinct class in the animal kingdom.

The course of his observation was this: — He asked, in the first place, What is the primary use of the mechanism, consisting, in the higher animals, of head, trunk, upper and lower extremities, and, in the inferior creatures, of parts corresponding more or less closely with these, which is supplied by this class of nerves? The answer was, to minister to the great function of Nutrition. These different members, he thought, might be regarded, taking this comprehensive view of the animal kingdom, as combining to form an organ by which the animal shall obtain nourishment.

This will be more readily understood, if we inquire what is the chief distinction between an animal and a vegetable. An animal possesses a system of organs in the interior of its body for elaborating and assimilating the nourishment received into it: now a vegetable has analogous organs, by which similar processes are performed; no distinction, therefore, can be drawn between them on these grounds. But there is an essential difference in the modes by which they procure their nourishment. The tree or plant is fixed in the soil, and obtains the nutritious juices which preserve it in life, by the roots that fasten it to the earth: the animal, on the contrary, is *locomotive*, and must transport itself from place to place, in quest of its food. Accordingly, the animal must be provided with certain endowments bearing reference to that peculiarity of its nature; and if we consider what these endowments are, it will be found that they are such as the system of nerves under consideration confers.

Let me enumerate the powers which an animal must possess to enable it to go from place to place, and select its food. First,

it must have organs of locomotion: fins, or paddles, or some analogous structure, if the creature be aquatic; wings, if it move in the air; or extremities and feet, if it inhabit dry land. Secondly, it must have certain prehensile instruments, constructed for grasping and securing its food; and these may be either tentacles, paws, or organs corresponding with the hand in man. Thirdly, it must have a special mechanism for receiving the food, and, if required, for triturating the material of which it consists, so as to prepare it for being passed into the stomach; that is, a mouth and jaws. Fourthly, the mechanism here described would be useless, if unaccompanied by the means of putting it in motion and regulating it; whence a nervous system becomes necessary, consisting of nerves of motion and organs of sense, and a central part corresponding with the brain. To these various structures physiologists have applied the name "animal" organs, to distinguish them from parts common to vegetables and animals, termed the "organic" structures.

Here, then, may be perceived the foundation of Sir Charles Bell's explanation of the functions of the class consisting of the spinal nerves and fifth nerve of the brain. He looked upon this system, in the highest animals, as the representative of a set of nerves which exists generally throughout the animal kingdom; and which bestows powers common to all creatures raised above the vegetable kingdom, whatever may be their mode of respiration. In man they supply the lower extremities, his organs of progression—corresponding with the structures in other animals by which they move from place to place in search of food: they are given to the arm and hand, his instruments of prehension—analogous to organs in the inferior creatures which are necessary for obtaining their nourishment; and they give power to the muscles of mastication, by which the food is prepared for the stomach—corresponding with the oral aperture and mandibles in all animals. Finally, these nerves bestow touch and taste,* senses which are possessed most generally by animals, and which may be justly considered the most essential to an organiza-

* The gustatory nerve, the special nerve of the organ of taste, is a branch of the fifth nerve.

tion adapted, in its comprehensive view, to procure nourishment. The senses of seeing, hearing, and smelling, which belong to a large proportion of the animal kingdom, in common with man, are to be regarded, in this comparative survey, as superadded senses; they are introduced into the animal frame, one after the other, subsequently to touch and taste, according as the creatures ascend gradually in the scale of existence.

Before quitting this subject, it is interesting to remark how the mechanism thus shewn to be superintended by the spinal nerves and fifth, becomes accommodated to the organ of speech, upon that structure being added to the frame, and in such a manner, that it still performs its original office in the most perfect way. This adjustment is accomplished by a series of changes being gradually wrought in the different organs subservient to the mouth, so that this opening, in ministering to the animal wants, shall have simpler duties to fulfil, and depend more on its subsidiary parts, when to its office of feeding it adds that of breathing. Thus in the inferior animals, the offices of progression, of prehension, and of preparing the food for deglutition, are shared by the different members, in such a manner that each performs, to a greater or less extent, the duties proper to the others. For example, the structures designed principally for progression are instrumental also in seizing and grasping: those intended chiefly for prehension assist in progression; and the mouth, so far from being adapted exclusively, in all animals, for mastication, is in some an organ of progression, as it is in a great many the principal apparatus for prehension. My limits prevent me from entering fully into this subject, or illustrating by example, how each of the offices here enumerated comes at length to have its own appropriate instrument, distinct from the rest. It may be sufficient, however, to say, that when the animal frame reaches the high condition presented in man, the *hand* becomes so perfect a minister to his animal wants, that the mouth is absolved from performing more offices than that of mastication simply. Hence this cavity is diminished in size; the teeth and jaws are reduced to moderate dimensions; and its form is consequently suited in the most admirable manner, for being the organ of articulate language

Thus, in whatever view we study the developement of the animal frame, new proofs present themselves of its being the final aim of all the modifications which we successively trace, to confer upon man an instrument adapted to his intellectual nature — an organ of Speech. It is the fine adjustment of the various members of his body for that object, that renders his organization the most perfect in the animal kingdom. Additional strength is, therefore, given to the author's opinions, that our conceptions of human beauty, both as regards the form of the head, and the moveable features, have a direct relation to the fitness of the structures, for Speech, Voice, and Expression.

Such is a brief account of the leading parts of the discoveries made by the author of the volume, in this important part of the anatomy of the body — the nervous system. He first established, on undoubted evidence, the fact, that the nerves of motion are distinct from those of sensation; and that the nerves generally possess different endowments, according to the divisions of the brain from which they arise. He then arranged the nerves of the whole body into three distinct systems, corresponding with the organs which they respectively control. The first class, was that composed of the spinal nerves and fifth nerve of the brain; this class, he proved, bestows both motion and sensation on all the parts to which it is distributed; and these parts, he further shewed, are organs which belong to man in common with the lowest creatures, their united function being to supply food, the first necessary want of all animals: he termed this set of nerves the "original" class, and included in it the various organs of the senses. The second class comprised in it a series of nerves, distinct from the former, both in their origin and mode of distribution: they pass off from a circumscribed central portion of the nervous system, the medulla oblongata, and diverge to different parts of the head, neck, throat, and chest already supplied by the original class: he shewed that these structures form together the organ of respiration — a mechanism which does not belong to the lowest animals, but is gradually introduced by a slow process of developement into the animal kingdom, in order that, besides oxygenating the blood, it may become, in man, the organ of

Voice and Expression: to this set of nerves he applied the name, respiratory class. In these two classes were combined all the nerves together which arise either from the brain or spinal marrow. The third class consisted of a series of nerves which have their centre in large ganglions scattered principally among the viscera of the abdomen. This forms the system called ganglionic or sympathetic: and their use has been generally supposed to be, to unite in sympathy those organs by which the various organic functions are performed: such as secretion, absorption, assimilation of the food, the growth and decay of the body, &c. When the nerves belonging to these different classes are viewed in their combined condition, as seen by the anatomist, nothing can exceed their apparent confusion; but when examined by the aid of the principle, and the arrangement, introduced by Sir Charles Bell, order and design are found to pervade every part.

THE END.

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